Solar Probe Plus

A NASA Mission to Touch the Sun

Integrated Science Investigation of the Sun
Energetic Particles

EPI-Hi Autonomy Review

11 November 2015

Sensor Overview

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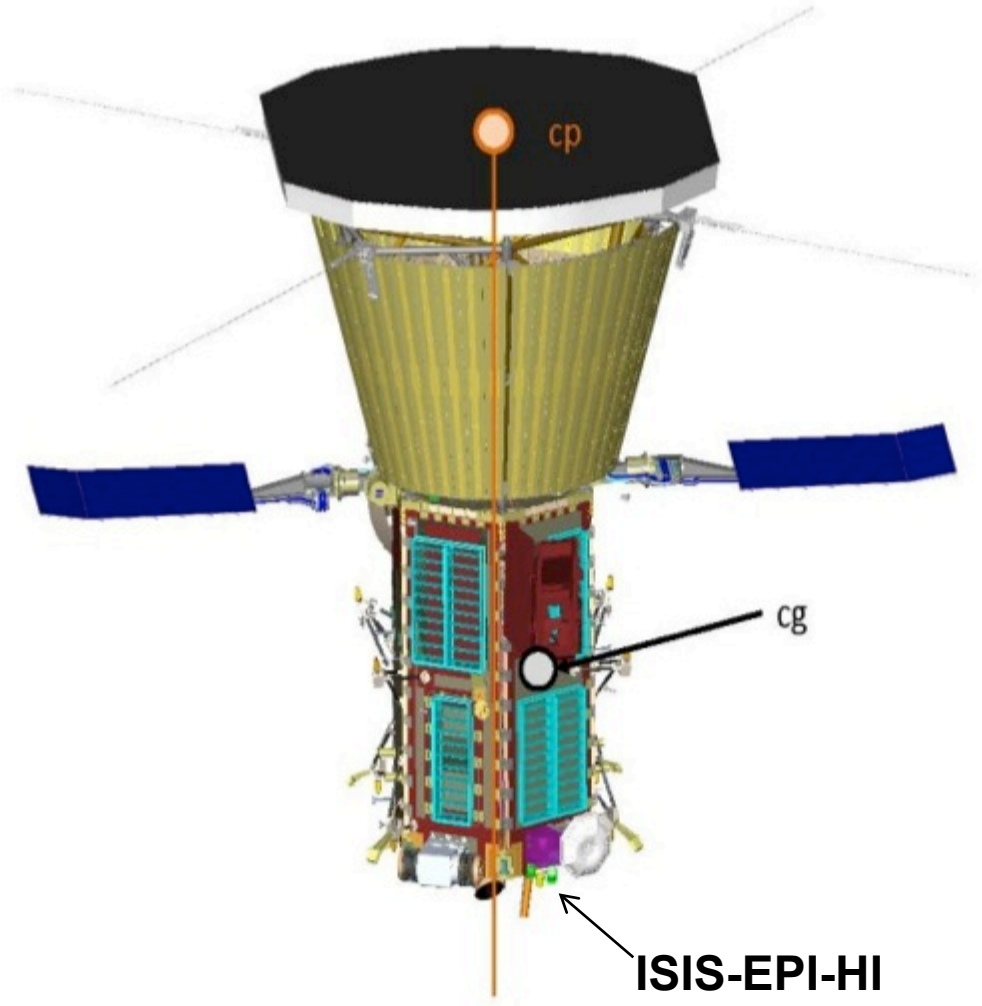
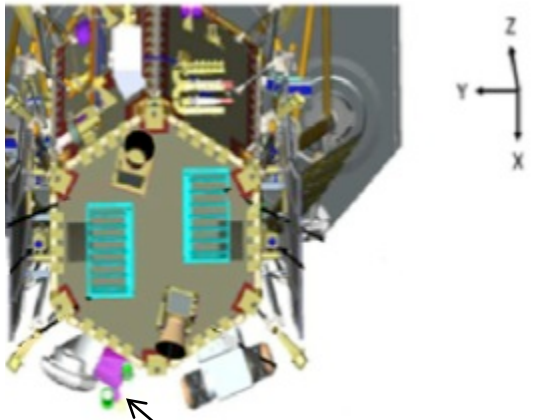
EPI-Hi Instrument

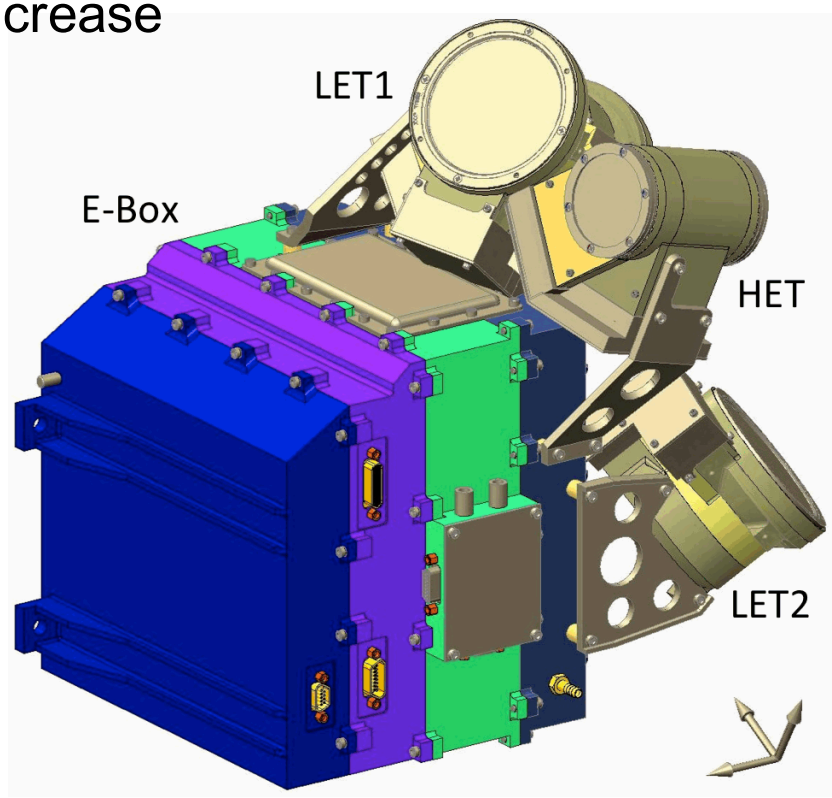
- Location of instrument on spacecraft





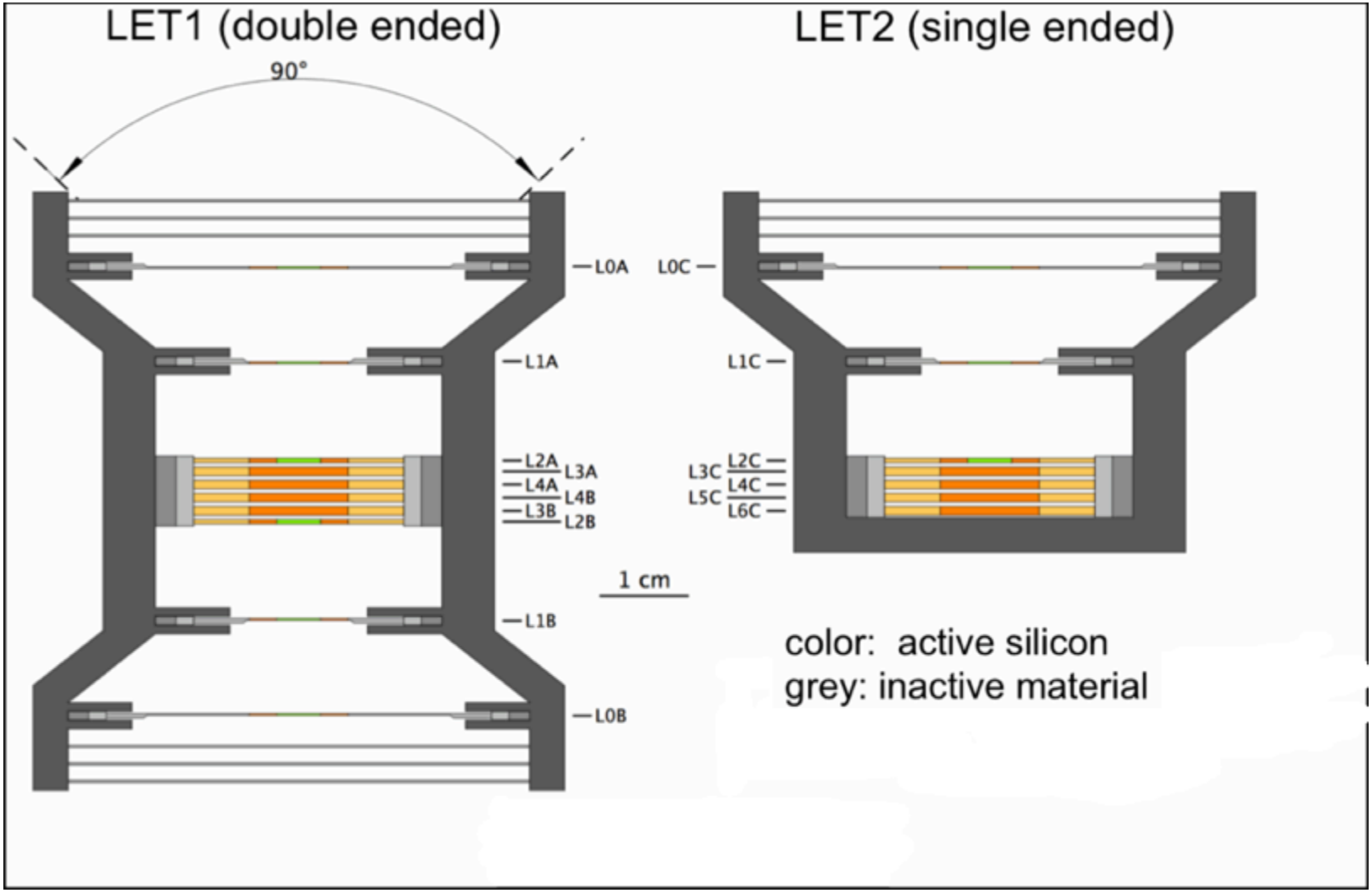
Design Overview

- Sensor Approach
  - All sensor elements are ion-implanted silicon solid-state detectors
  - Multiple detector telescopes to provide large energy range and sky coverage
  - Some telescopes double-ended to increase sky coverage
  - Detector segmentation to provide angular sectoring and adjustable geometrical factor
- Heritage
  - Numerous energetic particle instruments over the past 40 years
  - Direct predecessor: STEREO/LET & HET



Sensor Design (1/2)

Low-Energy Telescopes: Conceptual Cross Sections



Sensor Design (2/2)

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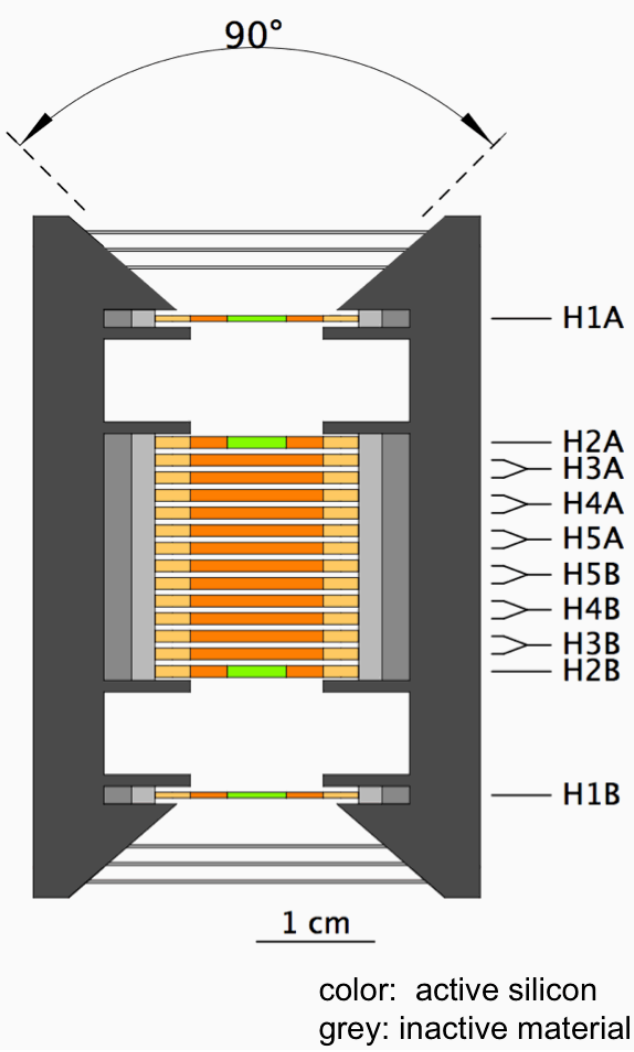
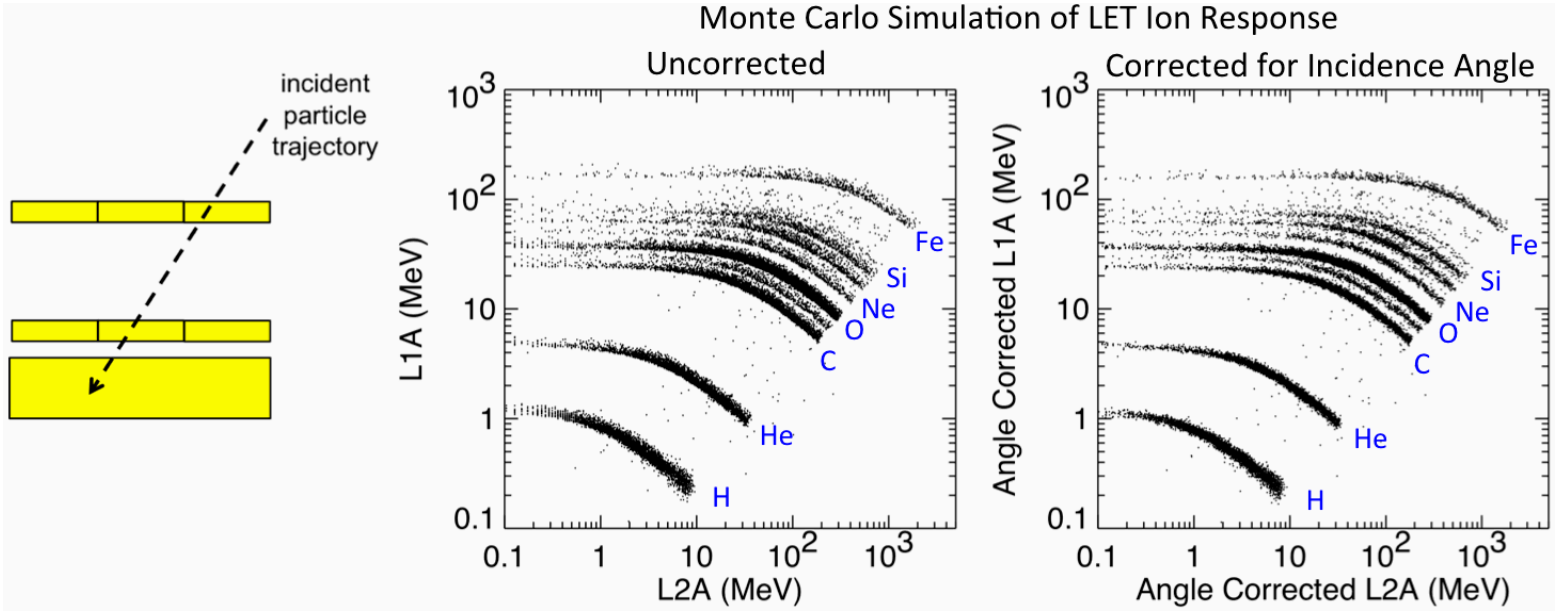
High-Energy Telescope: Conceptual Cross Section

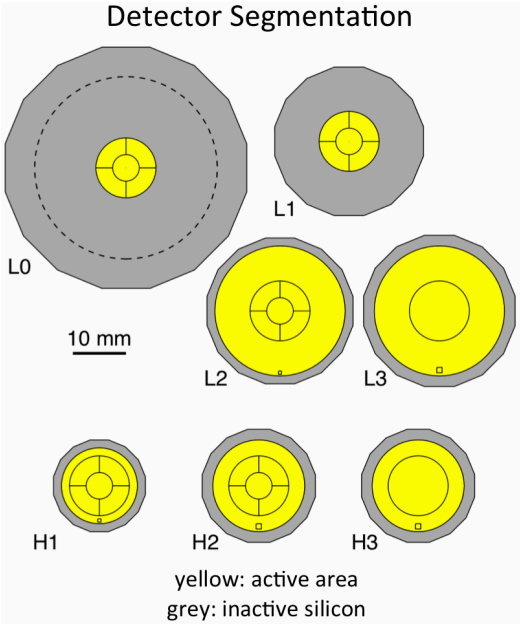


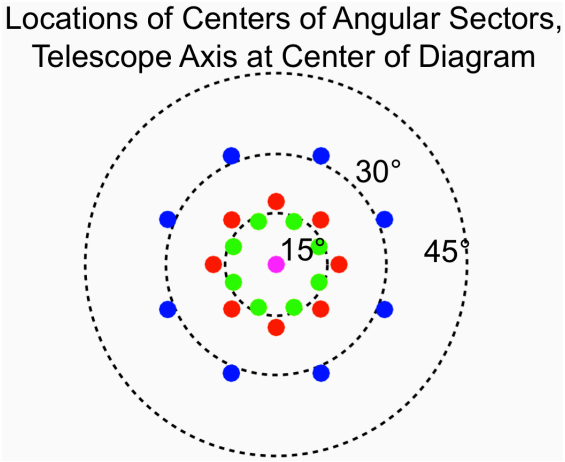
Principle of Operation



- Energy loss measurements from the detector in which a particle stops (E') and the preceding detector (ΔE) organize the data into distinct tracks for the various elements.
- Segmentation of front two detectors provides information about particle direction of incidence that is used to obtain mean thickness penetrated in the ΔE detector and make an on-board correction to the measured energies to optimize species resolution.
- Energy assigned on-board includes energies measured in overlying detectors and calculated energy loss in windows.

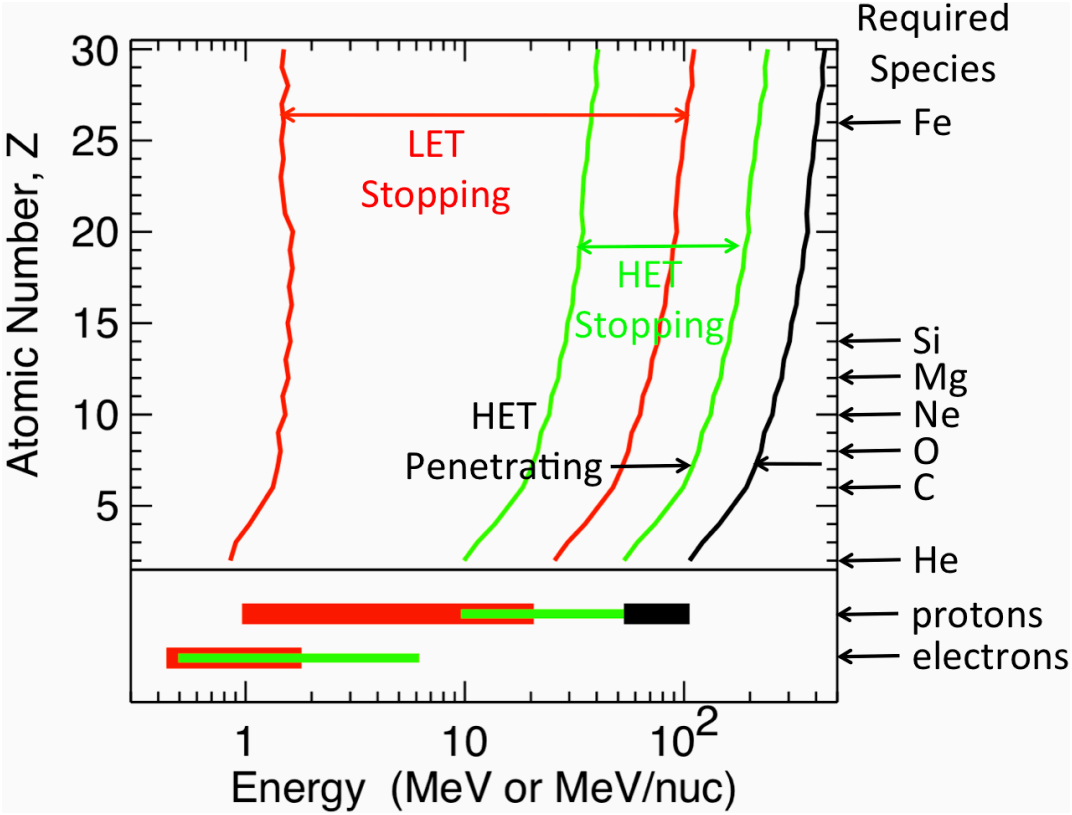
Angular Sectoring





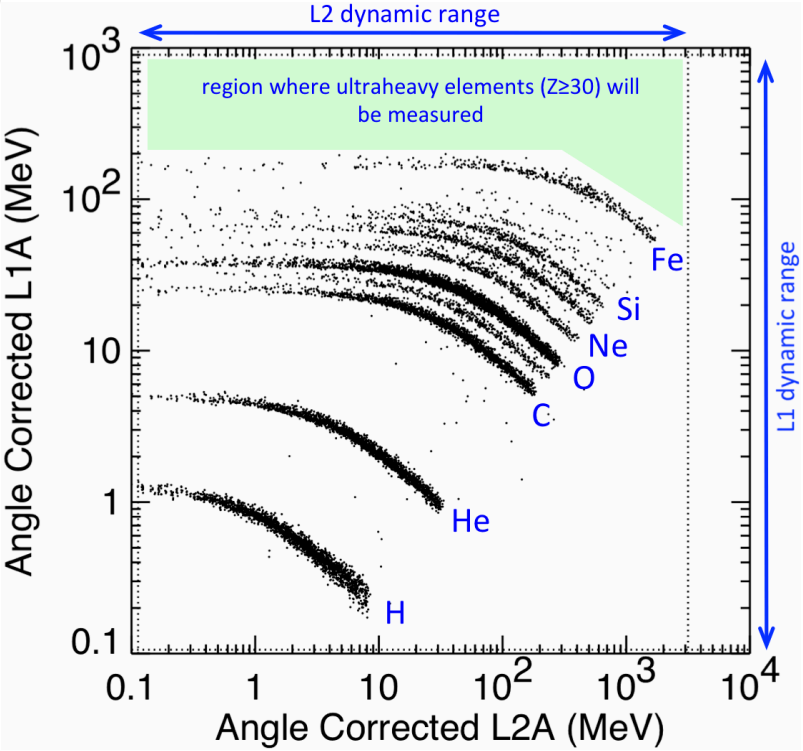
- Particle directions of incidence are determined based on active elements hit in two position-sensitive Si detectors (L0 and L1, L1 and L2, or H1 and H2)
- Each of these detectors has central bull's eye surrounded by 4 quadrants
- Quadrants in L2 (H2) rotated 45° about the telescope axis relative to those in L1 (H1)
- 25 combinations of hit elements in the two detectors are used to assign event to a viewing sector
- L0 and L1 have quadrants aligned to optimize mass resolution; at low energies 3 sectors rather than 25
- HET provides sectored electron data, LET1 provides only front-back direction information for electrons

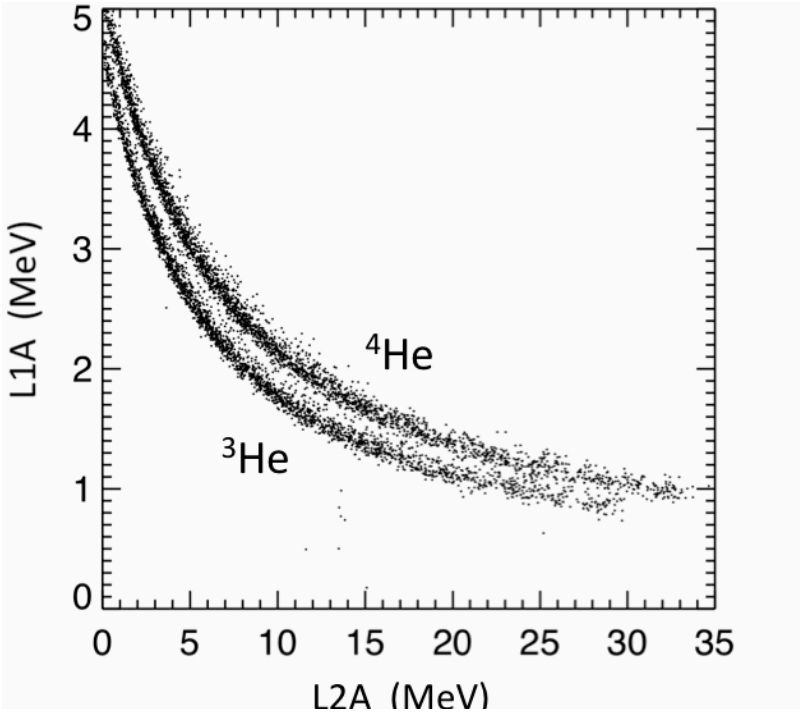
Species and Energy Coverage



- Rates are accumulated on-board in logarithmically spaced energy bins (> 6 bins/decade)
- Larger energy bins are used for some rates accumulated at the highest cadence (1 second) in order to increase statistical accuracy

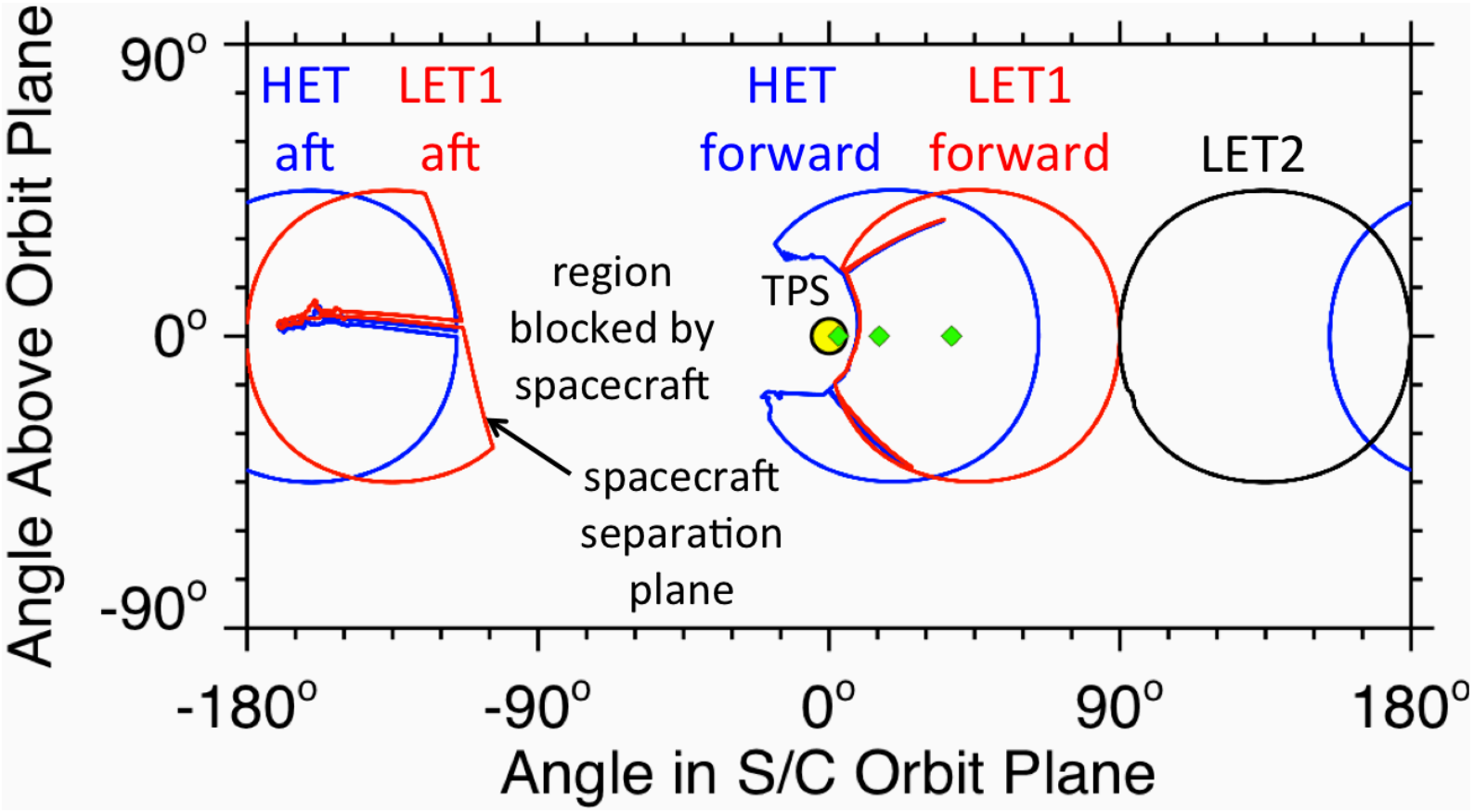
Element and Isotope Resolution





- Monte Carlo simulations shows that all required species are identified
- ^{3}He/^{4}He is a key measurement that needs isotopic resolution
- Simulations show that there is clear separation between ^{3}He and ^{4}He in a high-resolution subset of the events (particles with near vertical trajectories)

Fields of View (FOV)



- Sun (yellow circle) shown with angular size seen from 10 R_S
- Mean Parker spiral field angles (green diamonds) shown for 400 km/s at heliocentric distances (left to right) of 10 R_S, 0.25 AU, and 0.70 AU
- Full energy coverage in forward and aft regions of overlap between LET1 and HET

Measurement Cadences

- Highest cadence: 1 second
  - Used for one electron bin below and one above 1 MeV
  - Used for 4 proton bins above 1 MeV
- Intermediate cadence: 10 sec
  - Used for narrow energy bins for e, H, He, ^{3}He
  - Used for intermediate-width energy bins for element groups CNO, NeMgSi, Fe
- Normal cadence: 60 sec
  - Used for narrow energy bins for ^{3}He, and major elements from C through Ni
  - Used for wide energy bins for groups of ultra-heavy elements
  - Used for angular distributions in one broad-energy-range proton bin and one broad-energy-range electron bin
- Low cadence: 300 sec
  - Used for angular distribution of e, p, He, ^{3}He, CNO, NeMgSi, and Fe in intermediate energy bins
- Very low cadence: 1 hr
  - All rates accumulated at cadences of 60 sec and 300 sec are also accumulated over 1 hr

Dynamic Range in Particle Intensities

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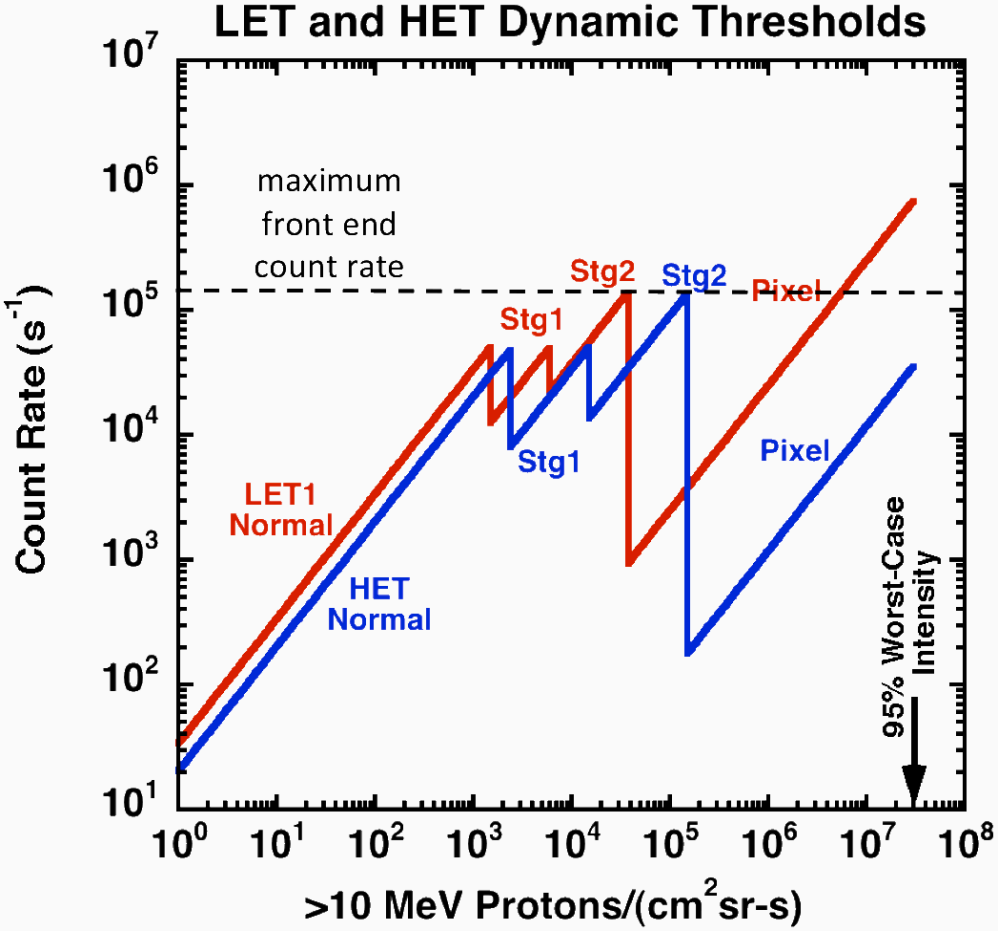
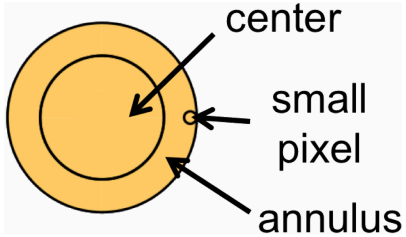
Effective collecting area for protons decreased during period of high particle intensities



- There is significant uncertainty in the radial dependence of SEP intensities close to the Sun
- The EDTRD includes a worst-case spectrum having a >10 MeV intensity of $3\times10^7/cm^2$sr-s (95% confidence)
- Both HET and LET use dynamic thresholds when intensities exceed ~2000 $/cm^2$sr-s
- In order to measure proton intensities in extreme events, singles count rates from several small (1 mm^2) pixels are used with thresholds raised on all other detector elements



Summary

- Operation of EPI-Hi is relatively simple because there is essentially only one science mode, although at times not all cadences for the particle rates are sent to the spacecraft SSR.
  - For example, during cruise phase (r > 0.25 AU) only the longest cadences are transmitted to greatly reduce data rate.
- Sensor has graceful degradation. Failed segments/detectors/telescopes reduce but do not completely disable science return.
  - Enhanced with flexible trigger equations
- It is very important that EPI-Hi collect data as much of the time as possible. SEP events can have durations of a week or more and gaps in the data can complicate the interpretation.